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Welcome everyone to the NOAA Central Library. I am happy to announce that our presentation is going to be by Dr. Jessica N. Cross. She is from the Pacific Marine Environmental Laboratory that focuses on ocean acidification monitoring and research in the Pacific Arctic and along the Alaskan coasts. She is particularly interested in the development of new technology and techniques that reduce the cost of collecting data over the expansive and remote Arctic region. -- please join me in welcoming her.

Thank you for coming. This is meant for a variety of audiences. There are some parts directed to scientists. And parts that are directed to policymakers and local communities to make decisions in their own backyard. I feel like as a scientist, it is part of our job to make sure we hit all of the different points. I hope everything you hear today is accessible, regardless of your background. It should be easily understandable. If you have questions, please type them into the go to webinar section. We will take questions at the end.

I will briefly start with a definition of ocean acidification. As atmospheric CO2 levels rise, this shows the data over time. This is the last five years. We have seen an increase in atmosphere CO2 levels since the Industrial Revolution. One third of the carbon dioxide is absorbed by the ocean. It is a natural process. On top of that, Alaskan waters are naturally very high in carbon dioxide. Even when you add a little bit, human caused or other, because the CO2 concentration is high it causes big changes quickly. The picture I am showing on the lower right-hand corner has a bunch of small fishing boats spelling acid ocean. It is from local fisherman participating in the Whale Fest, an environmental event that happens every year. Adding this to the ocean, is not turning the ocean acidic. It is making it more acidic than it was before. We are having acidic ocean events. That is an important distinction to make.

The very little bit of pH decline that we see is causing carbonate minerals to start dissolving. Low pH is corrosive, even to carbonate minerals at pH above seven or neutral. This particular slide is showing the excess amount of carbonate in the water column that is been produced as a result of this acidification. Their observations that we have already documented in Alaskan waters.

They could have big applications for the state of Alaska. First of all, Alaska is home to 60 percent of fishery by weight. These commercial fisheries form a lot of the economy. And part of the national economy as well. This dissolution is taking place in areas that we know are inhabited by particularly red king crab and blue king crab species. There is a potential for the CO2 to impact the commercially valuable populations. On top of affecting commercial industry in Alaska, these acidification driven ecosystem changes could threaten food security for many of the local communities that rely on local protein and local fishing.

We know the ecosystem changes should be happen in Alaska. It impacts shellfish. I'm showing the lifecycle of the crab. We will start out with the adults. Ocean acidification creates stress for adults, as a result the embryos, fewer larva hatching. The larva that do hatch do not necessarily survive. Or much lower percentage survive their juvenile stage. Those that do survive have stress results and it starts the cycle over again. As you can imagine, it results in a population decline.

We know the ocean acidification also impacts fish. Rather than a specific physiological development of fish, in particular ocean acidification affects the behavior. Which I am highlighting with the magnification glass. It interferes with sensory signals for some fish. We will talk about what that means later. Ultimately, it interferes with avoidance. They are not able to avoid predators or find prey. Which you can imagine affects their health quality.

We also know that for both of these shellfish and fish, ocean acidification impact their food sources. This is the OA poster child. On the left, this is a healthy pteropod shell and has been exposed to ocean acidification levels that you would expect to see in the are in the year 2100. It is susceptible to ocean acidification. As exposure continues, what first happens is the shell pits and then starts to lose mass. We know it is already happening in places around the ocean. It is not just a lab experiment showing it might happen. This is directly off the west coast and Antarctica. The same processes are probably happening in Alaska, even though we have not collected the data yet. These pteropods, in particular, are a food source for pacific salmon. They are impacted by the sensory interference from ocean acidification. They are happening their food sources interrupted. It is not clear if they can find a new food source if the pteropods were not present. The extra stress adds stress to the ecosystem.. It inhibits the normal function now the and operation.

The number one question I get at this point, regardless of who I am talking to, is what can we do? I am good as eight scientist at communicating what is going on in the environment. I am good at understanding the risks associated with those changes in the apartment. I am not necessarily great at community the human interaction behind it. Having seen just a limited number of slides, the community says I believe you, tell me what to do next work that is a part of the ocean acidification portfolio. Which is where I drew this figure from. NOAA dissipates in the U. S. climate resilience toolkits. Is essentially a source of resources. It says if you and your community are concerned about climate change, here is what you can do. There is a resilience cycle the rent you file. Start with understanding hazard and assessing risks. After that, investigating options, planning the action you may take and ultimately, taking action. Which sometimes includes additional expiration. The rest of the talk will be ingrained in the resilience cycle.. You can see were some of the ocean risk stands. Do we understand the environment? To understand the risks associated with the changes? What do we do after that? Step one, explore hazards.

I have shown you a small sampling of what the data looks like in Alaska. I also want to go into that in more depth. In order to make these observations and to understand the duration and intensity, the extent of the spatial variability of ocean acidification, we need to be able to build and OA network. We do that by trying to understand what is happening over time . They collect data over time, but also in one spot. We try to go out and understand what is happening, in terms of space. We want to build a system that works in time and space. We do that, using a variety of different platforms. Readerships, moorings, gliders and runs. You can see the ships are the black dots. The red triangles are moorings. They gliders and drones are the gray tracks that we have the most of the Alaskan coast. Alaska is very big. More coastline than the East Coast, West Coast, of Mexico and Great Lakes combined. On top of that, the shelf for the region is extremely wide. This creates a lot of territory for us to be able to cover. It is hard to do that.

We want to make sure we are building and observing system despite the challenges and remote locations and harsh conditions. Inexpensive area that we do our best to cover all of the ocean basis. We are unable to do that by using a portfolio of tools. Using all the tools in our toolbox. The last key tool in the toolbox are our partners. It is not something NOAA does by itself. We have key partners. In particular the University of Alaska Fairbanks Ocean Center. They have a ton of work they have conducted through their. Operation. On top of that, we work with small businesses. Small hatcheries, tribes etc. to monitor ocean acidification conditions . Shore-based stations. We have had the opportunity to work with the Alaska Marine Highway's to collect more data at a lower rate that we do with our own ships. It is created lots of opportunity and it is important for us.

Using this portfolio tool, so far, has been really successful. Be a -- relying on our community. We won a silver medal in 2014. We are proud of it. We use six different types of technology effectively to track glacial melt water coming out of this fjord and Prince William sound and moving down the coast. It was not something that had been observed before.. We were able to do it by deploying this portfolio of diversity. On top of that, we work hard to make sure we can extend our observation as much as we can and relating them to other proxies. And saying this means this other thing as well. To make measurements that get other data from it. We do that with are moorings. They collect a limited amount of data. We are able to accurately translate that into other variables. It is through three different sites throughout Alaska. It is been combined with relationship, collected by our shipboard missions. Together, it is a seasonal cycle of variables at the three sites. We have one in Southeast Alaska, what at the site outside Seward, and one off of Kodiak. Step two, once we have observed what is going on in the environment, whether or not it is happening, we want to understand what has happened as well. What the ocean acidification look like in the future ? And how will we respond? We work closely with colleagues in the national Marine fisheries service to understand the direct impact on the organisms. That is Bob working with a crab.

We want to understand the chemical data and biological response data into regional models to help us fill in the gaps in time, space so that we can understand what is happening, rather than just small periods. What we know from the studies is that ocean acidification of the future is likely to get worse. We will start at the first end of the modeling and move out to a finer scale. This particular model is based on a global model. It shows at the top, 2012. The cool colors indicate water that is acidified more than it is not. On an annual average, the water issuing acidified conditions. Because the ecosystem response. As we move down to 2050, the cool colors have spread by quite a large margin. Covering most of the city. By 210, most of the surface waters along the Alaskan coast are experiencing annual acidification. We also worked hard to make the projections easy on moorings. It is another proxy that has been applied to the morning data I showed previously. It is Southeast Alaska, Seward and Kodiak. These are projections that have been applied to the morning data. In this case, the warm colors are acidified water. You can see that especially in Southeast Alaska, the warm colors emerge sooner, as soon as 2020, then they do at the other two sites. We know there are spatial variances. We are working hard to combine both of these things into a regional forecast model. That modeling effort is being supported by the Arctic research program. This is just a brief output of what that looks like for the year 2009. You can see the cool colors are located near the shallower areas. On top of that, rather than just looking at the surface, the regional model cuts several layers in the ocean. So we can understand the variability of depth. When we are talking about ecosystem response, we do not want to understand which system it will experience it in the future.

We want to understand co-occurrence of ocean acidification. Ocean acidification does not happen in a vacuum. What I show here is a snapshot of temperatures over the North Pole. This is from the Washington Post. As you may have heard, another extreme heat wave had struck the North Pole. Scientists had never seen so little ice in the Bering Sea. The warm temperatures led to massive ice loss. We know this is unlikely to abate. It is likely to continue in the future. This is just another major stress. We have multiple structures, warm temperatures, ice loss, oxygen is getting depleted in water, and now we are just starting to deal with ocean acidification . If we are only focusing on ocean acidification, we are missing a much larger part of the story. We work closely with our partners to make sure we understand the ecosystem. This particular study incorporated several of the structures in a population metric, based on current management levels for crab history. And organism cannot adapt and the barrier could lead to a collapse. In particular, the challenge is understanding when impacts might emerge. If we understand ocean acidification is not happening, there is not a change in ocean. It is able to cope. If we assume ocean acidification is happening and it happens at a constant rate, that happens much sooner, we may see impacts as soon as 2035. If we incorporate an nonlinear rate, that response may be delayed. However, it is important to remember, that if the response is delayed, it does not excuse us from needing to find a capacity to do something now. We need to start preparing for what that challenge might look like. Otherwise, if we wait until crisis happens, there is no opportunity to avoid it from a sustainable management standpoint.

We have taken that risk, with the crab fishery and combined it with other risks. We know that Pollack are more vulnerable resilient. Whereas crab is more vulnerable. We combine that with sociological data. It shows how much a community relies on fish. Either to earn money for the local economy, or to get protein. If they eat these fish primarily. What is a collapse in the preparation do? On top of that, whether or not they have a diverse enough economy that they can shift to finding other proteins or other jobs? The vulnerabilities combined with the demographic data created a rich assessment for fisheries. The blue areas are better able to cope with ocean acidification. They are slightly more resilient. The area in yellow is moderate and the red areas are extremely vulnerable. Those areas are located along the coasts were fishing is one of the only jobs that you can get. And also small rural communities were fish form the primary source of protein. We know that it is likely to Southeast Alaska may struggle first. As I pointed out, Southeast Alaska will experience ocean acidification sooner than the other sites. What we do for Galatians from a solitary perspective, that is shown. The duration of the acidified conditions increases much more rapidly than the other sites as well. If we choose a place to focus on, as one of the areas for ocean acidification, we might consider focusing on Southeast Alaska. That is the science. What is happening, in terms of environmental changes? What risks do those changes post? For the most part, scientists back off and say it is your responsibility. They back away from the community and decision-makers. I still think there is a role for us to play.

One of the questions that I get the most often is can we grow seagrasses to combat ocean acidification? I'm glad I have a relationship with the local community that they know to ask questions. The truth is that seagrasses and other phytoplankton soak up carbon dioxide during the day. If you think back to high school chemistry, they breathe carbon dioxide just like we breathe oxygen. The theory is that if you grow seagrasses, you might be able to pull carbon dioxide out of the system. We do not know that yet. There is conflicting evidence from ongoing studies. In

Korea, Maine and Washington state. I want to stressed that any impact is likely small and localized. The challenge is that any benefits they may have during the day, may go away and night. It may also be taken away as ocean circulation happens. There may be nonlocal benefits. Going at are in and around your hatchery -- growing it in and around your hatchery, may show benefits for their way. Some studies show it may hurt the environment more than it helps. Adding CO2 to the water in your community. We are not sure the benefits will merge. Even if they do, it would take more than seaweed to deal with ocean acidification.

By contrast, research indicates that one of the best things we can do to combat ocean acidification is to try to build resilience in the community. That is why we are operating in this resilience framework. We want to make sure that we have a good relationship with the communities. And the communities have a good relationship with the decision-makers. So that when it emerges, everyone has an opportunity to be on the same page. And everyone has an opportunity to medicate with each other about the decisions -- communicate with each other about the decisions. There are many scientists that are participating actively in this. The ocean acidification program and the integrated system sponsored the Alaska ocean as a vacation network. They are regional networks designed to connect scientists directly to stakeholders. I want to point out that these teams are not formed primarily with scientists doing public outreach. There formed from stakeholders in the community. We try to get scientists on these communities -- a few scientists on these communities, because we want to make sure the communities have a voice. We have tribes for the Alaska shellfish, growers associations, tribes, small businesses etc. These are the people we want to communicate with. Actually, in Alaska, I feel it is one of the best regions in the country to work with. Alaskans are so close already. They already have a resilient community structure.

To put it simply, Alaska cares. All of these organizations that you see listed here have either helped us are communicated their priorities directly to us. Actually, if you do the work, ocean acidification awareness in Alaska is three times higher than the rest of the United States. It is documented research. Alaska is doing a really good job in hearing about ocean acidification and understanding ocean acidification . It is working into the resilient framework. Some of us scientists are participating in AdaptAlaska. A program focused on climate change and developing climate resilience. Not just focused on ocean acidification . Also focused on coastal erosion. Things like ice loss, wildfires etc.. By participating in the larger client brilliance efforts, we are doing a lot to take action already on climate change in Alaska. I was proud to be a small part of this. For those of you who are here, tomorrow is the bronze award ceremony for NOAA. A member of the national Ocean service was awarded a bronze medal for her participation in this program. We are working hard to make sure we are connected as scientists, stakeholders and members of the community. To help the community change the goal of resilience in the future. We also have hatchery adaptation partnerships. We are working rectally with small businesses to help monitor ocean acidification in the region. We have the hatchery that is the longest partnership. We just started the partnership with oceans Alaska, another shore based area. We are working rectally with a tribe to monitor conditions there. Those are small businesses that are already taking action, based on the relationships with us. Not everything paints a pretty picture in Alaska. We are not ready to say, you are resilient. Check the box and stop working on climate resilience in Alaska. It is the beginning of what will be complex processes that involve different voices and stakeholders. And a coproduction of knowledge.

As a scientist, I can tell you how the environment is changing. I can tell you what the risks might be work I do not know what that means for your group. I don't know what that means for your capacity to take action. Listening to local stakeholders is a big part of my job. So that I can come back and say, maybe if we put this here or I can write a grant to help with this spot of uncertainty. That is valuable to me also. Sometimes, the next step of the process is to not just take action, but to continue to explore hazards. I mentioned Alaska is big. Our capacity to make observations in Alaska because of that is limited. We have models and proxies to extend our observation, but making more observations is a big priority. I work with the technology development program that is trying to turn autonomous vehicles and to ocean acidification platforms . There able to elect more information without a human cost or human risk. The picture I am showing is a drone. It is 20 feet long and 20 feet tall. It is difficult to see scale from this image. Last year, we are able to put equipment on a sale drawn we are making sure that we can capture multiple different carbon parameters and turn into a device that can measure ocean acidification in the future. The development is ongoing. I am proud to say a bronze medal was won by our team.

Going forward, we want to listen to the communities and understand what their priorities are in particular, one of the species we do not study that much is pink salmon. There are some colleagues at the University of Washington that are starting to study it. They are interested and pray quality and pray quantity. This have to do with the olfactory responses and their capacity to migrate. They are just starting this research. We do not know exactly what is happening. We do know there olfactory system is kind of walkie. We are excited to continue that work. Those online, I wanted to show this side. I want you to be able to contact us if you have questions. Or if you want to talk again, I am happy to give this talk to a local organization the webinar. We have the umbrella manager for the Alaska operations, which is Tom hurst. I am Dr. Jessica N. Cross, the primary observer for this program . Tom works on fish. Bob Foley works on crab. Bob Stone works on corals. Mike Dalton is the economic person. With that, I will close. I will take any questions. I will look to the room moderator. [Applause]

Are there questions in the room?

On your first slide, you showed the concentration of CO_2 . What evidence do you have?

It has been well committed that the increase is associated -- well documented that the increase is associated with the industrial revolution. If you're interested in learning more, I have plenty of resources

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Why is the concentration of CO_2 naturally higher ?

Cold water holds more carbon dioxide naturally. The situation pathway connects all of the ocean -- there is a circulation pathway that connects all of the ocean. The water has traveled along the bottom for somewhere between 900 and 1100 years. Lots of matter has fallen through. As the organic matter has expired, it creates carbon dioxide. The net impact of all the respiration eventually ends up in the waters.

From the NOAA enterprise risk perspective, how is ocean acidification affecting NOAA programs ?

I am not sure what you mean?

Is ocean acidification going to impact not sure -- national fisheries service? Will they go into their budget?

We are just 13 to work on those ideas -- just starting to work on those ideas. We make measurements because we want to understand the impact on fisheries. We are just starting to get to the point where we are taking about evidence managed based programs. We want to manage fisheries in a sustained way. We want to understand how to do that. Throughout the ocean acidification pogroms -- programs by we are just getting to where we understand what that means. If you have questions about the budget associated with that, I would direct you to those working with the national fisheries service.

We have a certification program with the atmospheric research program. It continues to be envisioned as a place where we integrate and correlate. We have money that comes in and out. We find the fishery service to do that. We are funding the national Ocean service to work on sanctuaries and modeling. We have money going to the OAR lab . We also leverage and there is a whole part of it that focuses on fisheries. Several employees are doing the research. It is coordinated and is and integrated effort.

From the NOAA enterprise risk perspective, do see this will be such a big problem that NOAA will have to focus and take resources away from other programs and apply it?

It has not happened yet.. Congress has in -- we are leveraging. There is so much we do not know about the vulnerabilities. It is hard to imagine putting all this money into ocean acidification work. It is definitely important . We will see.

We have a few questions online. This is a multitiered one. Is there anything that the inland states fish and consumer can do to help?

Is there anything that inland states fish and shellfish can do to help? The first thing is to educate yourself to understand that ocean acidification has the potential to impact you. For the cost of fish and shellfish that you eat in restaurants. Supporting ocean acidification research and research in general is important. I would also say, that the next thing you could do is to talk to your local community. About what climate risks you are facing. Even if ocean acidification is not a big interest in for example, Kansas. There are things you are expressing.

Is it possible to create a route to recover those on edible shells?

I am not sure which shells you are referring to? I will assume pteropods . Or -- if you're talking about pteropods, there is a mechanism . If you're talking about something to create buffering capacity to create resilience to ocean acidification , just like growing seagrass, and has the potential for a small overall and of it. It will be spread out over a long time. The cost associated with that is high. We do not want to focus on that as a cost effective opportunity to mitigate ocean acidification.

He was discussing oysters. Can big multinational seafood industry do more or do something?

Yes, multinational industry can be a part of this process. I would highly encourage you to talk to the ocean acidification network. We have subgroups that is part of the network. They are interested in grant writing and funding for ocean observation. You have the opportunity to go out and collect data. Because you fish commercially. Those who have the opportunity to collect measurements, we would love the opportunity to talk about it. I will say, we have a limited supply of equipment. The best investment you could make is to partner.

They are not familiar with the Omega figure in your slides. What does it translate to in pH? The CO_2 went up in five years.

You are talking about the Omega figure. The question in particular is essentially about what is Omega and how do you translate? Ocean acidification is measured effectively by Omega. Omega is essentially point at which carbonated minerals are likely dissolved. The lower the Omega figure the more likely carbonated minerals are dissolved. The higher the figure, the less likely and more resilient the carbon minerals are to the south. We use this to understand the impact of ocean as a vacation because -- impact of ocean acidification . There are different kinds of calcium carbonate. When we talk about the most often is Megan Knight. -- Dragon -- oraganite. adults crab builders out of something much hardier. However, the juvenile stages of crab build it out of oraganite. after that, ocean acidification measured by Omega, which has an impact for blood pH, also impacts crab. Which is why I talked about it for population cycle. Do we know how rapid ocean acidification is happening in Alaska.

The tried -- timeseries we have collected so far has only been for a couple of years. We know at this point, under saturated one -- water with low Omega value is likely to dissolve carbonate Ménière's. We make observation and we know something is dissolving. Even if we do not know what it is. If it is dead pteropods shells , there is no marker for each molecule of extra calcium. And which one is coming from a particular source. They all look the same. And so, we know at a baseline, OA is likely to be having those impacts. As for how fast it is changing, there is spatial variability around Alaska. I would not quote any rate to you right now.

Are there -- are the additional ice free days creating additional challenges in observation?

Additional ice free days providing challenges to observing? When you go out on ships, you have to plan in advance. When something happens, like it did in February, there is not the capacity for us to be able to respond. We cannot be there to capture the signal because our estimates are not there it is we were expecting ice. We want to take good care of our equipment. The biggest observational challenge is to get out there and respond to this adaptively with agility. We want to be able to meet the signals when they start to happen. New technology will be a big part of that. Being able -- once the drone is more highly developed we would like to launch that as soon as it is safe every year. Rather than having to plan years in advance. If we are working hard to make sure we are able to design a divided system mother has a rapid response.

Last question it does not sound like there is a solution to the issue. The prognosis is to adapt to the change that is to come from ocean acidification .

Sometimes it does not sound like there is a solution. Sometimes, when I give this talk, I say we have the observation that the opportunity to do nothing and see what happens. We have the opportunity to adapt by building resilience. Or we have opportunity to suffer the consequences.

We want to make sure that rather than to see what happens or deciding we are comfortable suffering, we give the communities who are at a high risk the capacity to adapt. I want to make it clear that there are winners and losers. It is not that all Alaskan fisheries should get out of the business now. That is not what I am saying. Please do not take that soundbite out of context. That is not what I am saying. It may be for example, you switch to a different fish. We will still have fish. It may be we are able to safely manage the fisheries through ocean acidification . We are able to continue to harvest the same fish. It may be that we have to change the location where we fish. Some populations may be threatened, were others are okay based on the mobility. In order to find out those answers and create sustainable management around fisheries, we have to understand. We have to link it up to a system. That is one of the places, at least in terms of the science entity, we try to coproduce the knowledge. We would not be able to do it without you guys telling us your priorities. And vice versa.

Are there any more questions?

Thanks for joining us. [Applause]

I will make one more pitch for the ocean work. It is run by the Alaska observing system network. Email if you want to get involved.

Thank you.